A Proposal Submitted to the Utah Division of Air Quality

Science for Solutions Research Grant Program

Summary Information Page

Project Title: Development of Top-down Hydrocarbon Emission from Oil and Gas Production in the Uintah Basin

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Funding Requested:

We request $106,095 from the Utah Division of Air Quality to carry out this project. U S U will provide $12,730 in matching funds.

Project Period:

The project will begin on 1 July 2021 and end on 30 June 2023.

1. Abstract

In this project, we are proposing to use a method known as top-down emission estimation to refine Volatile Organic Compounds (VOCs) emissions from oil and gas production (O&G) based on long-term surface level measurements of methane (CH_4) and hydrocarbons in the Uintah Basin (UB). The objective of this project is to *improve the Utah Division of Air Quality (UDAQ)'s bottom-up Uintah Basin Emission Inventory (UBEI),* which is critical information for developing a regulatory model for the State Implementation Plan (SIP) to attain the ozone (O_3) standard. This project will be conducted as a collaboration of Utah State University (USU) and University of Utah (UoU).

Emissions of CH_4 in the UB will be estimated using the Stochastic Time-Inverted Lagrangian Transport (STILT) model, then VOC emissions will be estimated based on CH_4/VOC-species ratios. Here we make use of the near surface long-term observations of CH_4 in the UB, coupled with VOC observations, to scale up the VOC emissions to the Basin level and probe multi-year shifts in VOC emissions. Finally, top-down emissions, as derived with this method, will be utilized in a photochemical model and evaluated for ozone performance. Our proposed project would address one of the goals and priorities defined in the RFP: (IV) Emission Inventory Improvements. The project leverages long-term measurements of CH_4 by UoU and VOC by USU from stationary stations and from recent USU's mobile cannister samplings in the UB.

2. Basis and Rationales

Areas of the UB below an elevation of 6,250 feet have been classified by the U.S. Environmental Protection Agency (EPA) as a marginal nonattainment area for ozone. Due to the number of O_3 exceedance days that occurred during February and March 2019, the area is certain to become a moderate non-attainment area when EPA re-assesses its attainment status in 2021. The designation as a moderate non-attainment area will trigger a requirement for UDAQ (and EPA and the Ute Tribe for areas of the Basin that are Indian Country) to develop an Implementation Plan that brings the UB into attainment of the EPA O_3 standard. As part of this plan, UDAQ will be required to develop regulations to reduce emissions and show with three-dimensional photochemical modeling that those regulations will reduce O_3 enough to achieve attainment of the standard. An accurate emission inventory, especially emissions from oil and gas production (O&G), is crucial in developing of such plan.

CH_4 is predominantly emitted from O&G activities in the UB: earlier work has indicated that CH_4 emission are as high as 10% of natural gas production in the UB ([1], [2]). Our long-term methane measurements in UB show that enhancements in CH_4 concentrations over baseline values have been decreasing in the recent years (Fig. 1 and 2). We recently carried out a top-down analysis combining the observed methane concentrations with atmospheric modeling using the Stochastic Time-Inverted Lagrangian Transport (STILT) model and found that methane emissions in the Basin have decreased from 45 metric, tons.hr^{-1} in 2015 to 20 metric tons.hr^{-1} in 2020 (Fig. 2).

Meanwhile, the trend in VOC emissions from UB O&G production, according to inventory estimates, does not show the same pace of decline: the combined VOC emissions in Duchesne and Uintah counties are 90,383 tons.yr^{-1} in 2014 [3] and 103,723 tons.yr^{-1} in 2017 [4]. Such increase in VOC emissions contradicts the observed trend of CH_4 emission as discussed above. Furthermore, the increase of O&G emissions from 2014 to 2017 also contradicts the decrease of O&G production in the same period as obtained from Utah Division of Oil, Gas and Mining[1]. Such contradictions highlight uncertainties in determining the appropriate version of UBEI for studying ozone in past and future years. Thus, there's urgent need to develop a top-down emission inventory that complements the bottom-up information from UBEI.

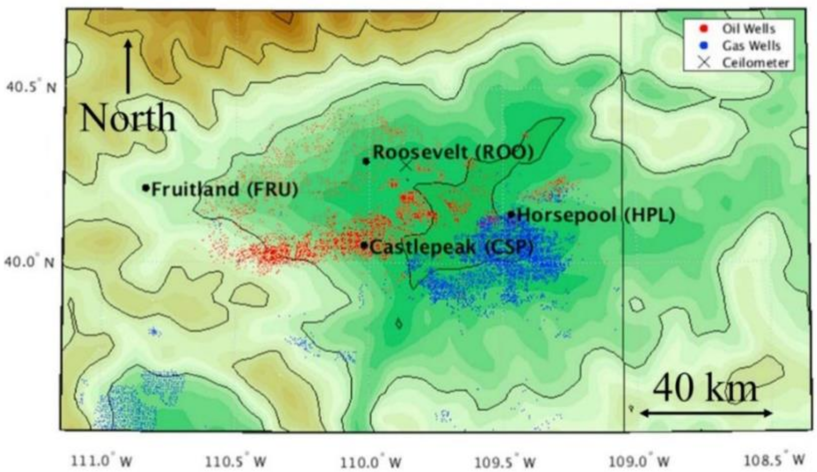

Figure 1. Map of Uintah Basin showing the location of the Fruitland, Roosevelt, Horsepool, and Castle Peak observing sites. The Fruitland site serves as a background site against which the enhancements at the other 3 sites are calculated. The red dots are active and producing oil well locations. The blue dots are active and producing gas wells. The black "X" indicates the location of a ceilometer that can be used to assess the extent of vertical mixing in the atmosphere, as well as in the model. From [2].

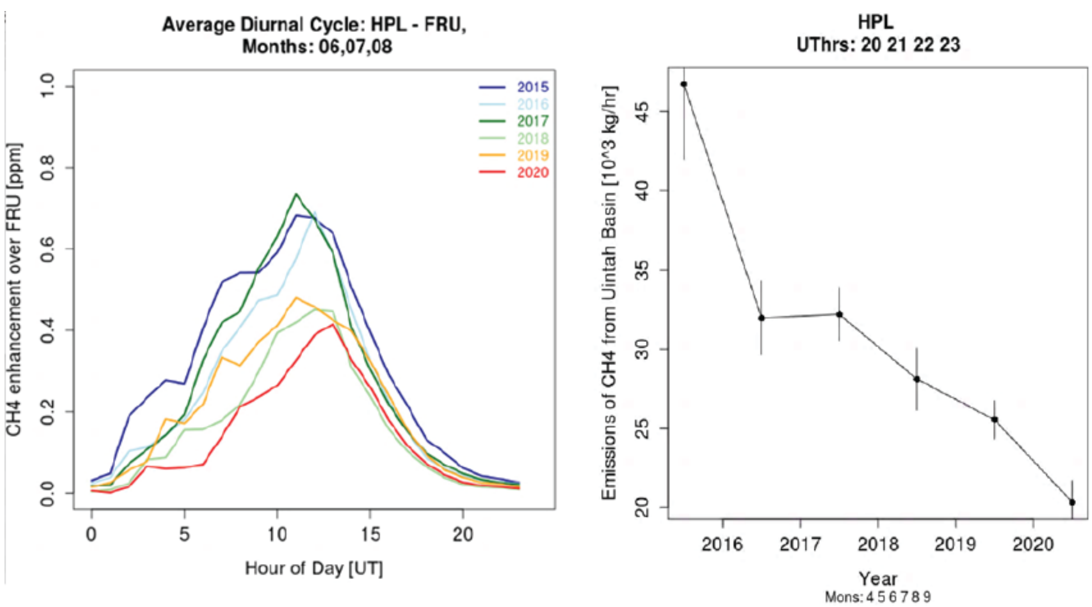

Figure 2. (Left): Summer-time observed CH_4 at Horsepool as enhancements over the baseline values observed at Fruitland over the years of 2015-2020. (Right): Emissions of CH_4 from the Uintah Basin, calculated via a top-down method that combines observed CH_4 enhancements with atmospheric transport from the STILT model for the months of April through September.

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[1] https://oilgas.ogm.utah.gov/oilgasweb/index.xhtml

Another well-known discrepancy in the UBEI is lack of information on VOC compositions of various O&G source activities. Most photochemical modeling studies in the UB were unable to reproduce the high ozone episodes during wintertime (e.g., [5], [6], [7], [8], [9]) which is consistent with our modeling effort in the UB (Fig. 3). Adjustments to the bottom-up emission inventory, particularly to VOC emissions, are needed for simulating high O_3 level. Our recent modeling study for winter O_3 2013 in UB with using UBEI2014 [10] showed that while simulated total organic compound concentrations are within the same range as reality, the simulated concentrations of many reactive organics are much too low (Fig. 4). This finding indicates that the model discrepancies are not caused by underestimation of total VOC emission but rather by the fact that application of VOC composition data results in modeled reactive organics that are lower than reality. Using the updated UBEI2017 with the increases total VOC emissions would potentially increase simulated ozone, but it is doubtful that the reactive organics will approximate observed values if using the same VOC composition profiles. Developing VOC composition profiles for a specific source categories, such as in the Uinta Basin Composition Study [11], is often expensive and take time to complete. VOC composition profiles that can be quickly developed basing on ambient air measurements and verified with dispersion and photochemistry model are useful in identifying gaps in the emission inventory and prioritizing source categories to be studied on.

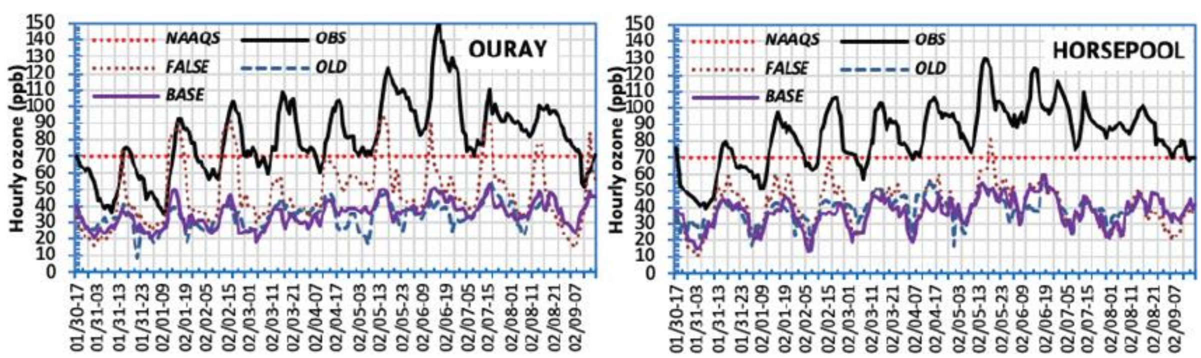

Figure 3. Comparison of observed (OBS) and modeled ozone concentrations under different scenarios (BASE, OLD and FALSE) at Ouray and Horspool. OLD, BASE and FALSE scenarios represents simulation with various meteorological conditions and VOC composition profiles. Taken from Section 10 of Lyman et al. [10].

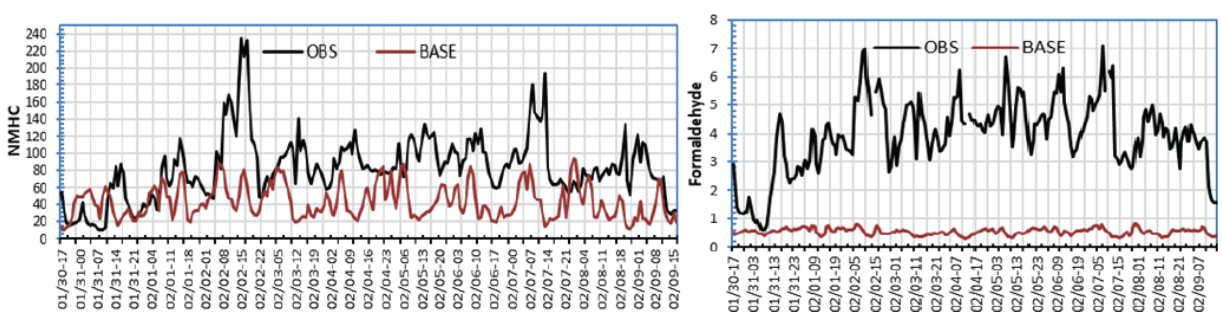

Figure 4. Observed (OBS) and modeled (BASE) nonmethane hydrocarbon (NMHC) (top) and formaldehyde toluene (bottom) at the Horsepool monitoring station during January and February 2013. Units are ppb. Taken from Section 10 of Lyman et al. [10].

Utah State University (USU) has received funding from UDAQ to conduct “Improving Volatile Organic Compound Emission Estimates for the Uintah Basin” (VOCUB) from July 2019 and is set to completed by March 2021. One of the expected outcomes of the VOCUB project is a version of top-down EI developed based on slope of CH_4/VOC derived from distributed canisters sampling system deployed in wither 2019-

2020 and winter 2020-2021 in combination with the use of methane gridded bottom-up EI from [12] or from [13]. Another expected outcome is a detailed comparison of VOC composition profiles that are being employed in photochemical model to the ambient VOC compositions measured by the distributed canisters.

In this project proposal, we will combine data that has been produced from the VOCUB study together with long-term CH_4 and VOC measurements that have been conducted by researchers at University of Utah (UoU) and USU in the Uintah Basin to scale up the VOC emissions to the Basin level and probe multi-year shifts in VOC emissions. Here apply an alternative approach to method applied in the VOCUB in developing top-down EI and VOC speciation profiles.

Objectives: Our objectives for the proposed project include:

(1) Developing multi-year (, 2020, 2021 and 2022) top-down EI of CH_4 and VOC basing on their ambient measurements and with using STILT transport model.
(2) Improving VOC composition profiles for certain O&G source categories using ambient measurements.
(3) Evaluate impact of the bottom-up UBEI and top-down VOC EI on simulating high winter ozone episode in the UB.

Alignment with FY 2022 Science for Solutions Goals and Priorities: Our proposed project would address one of the goals and priorities defined in the RFP: (IV) Emissions Inventory Improvements, with a focus on "reconciling differences between inventory estimates and observations" and "improved representation of emission sources and their estimated activity, spatio-temporal distribution and chemical speciation" for modeling of ozone in the Uinta Basin. Our proposal also focuses on studying "Methane emissions & ozone formation impacts" in the Uinta Basin.

Measurable Benefits Utah DAQ Can Report to the Legislature:

Our project aims at assisting UDAQ's mandate in helping the state of Utah meet federal air quality standards and for Utahns breathe healthy air. With the developed multiyear top-down VOC emission inventory from this study, UDAQ will have a reference dataset to evaluate, identify gaps and improve its bottom-up UBEI which is a critical component for the ozone SIP model for the Uinta Basin. With a comprehensive and well evaluated emission inventory, UDAQ would gains confidences from stakeholders, especially from oil and gas industry, in the results of its SIP model and the emission control strategies it proposes.

3. Technical approaches

Task 1: Development of multi-year top-down EI of CH_4 and VOC

We will determine the slope factors of CH_4/VOC at the Horsepool, Castle Peak and Roosevelt monitoring stations (Fig. 1) for multiple years since 2019. Initial analyses from the winter of 2019-2020 indicate strong correlations between CH_4 and most organic compounds (Fig. 5) which means CH_4 emission is an effective surrogate to deduce emissions of other VOC species.

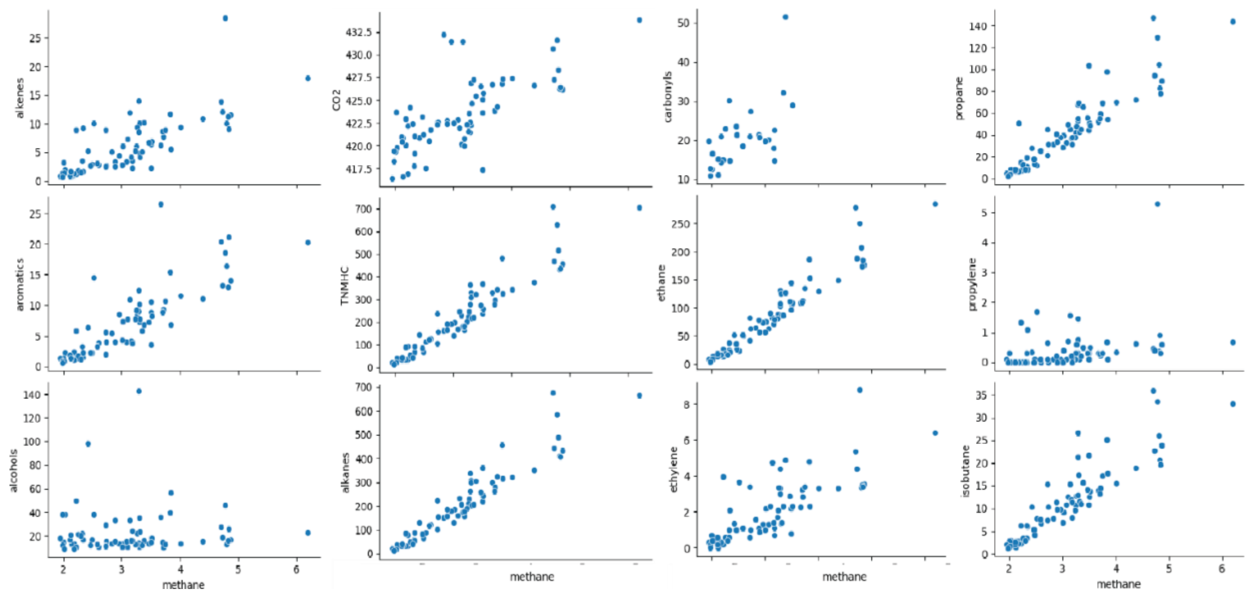

Figure 4. Correlations of concentrations of CH_4 to other VOC species as derived from measurements during winter 2019-2020 at Horsepool monitoring station. The deduced slope factors (ppb/ppm) of CH_4 to total VOC, alkanes, alkenes, aromatics and alcohols are 174, 165, 4, 5, and 0.8, respectively.

We will perform HRRR-STILT simulations (see section 4 for model configurations) for selected cold-pool episodes in past winter season from 2019 through 2022 with Horsepool, Castle Peak and Roosevelt monitoring stations selected as receptors and identify their source region (aka "footprint"). This approach is similar to the approach applied in [14] to quantify CH_4 emission (Figure 5). First, hourly averaged footprints will be determined for each receptor. Then, CH_4 emission for each the footprint will be determined using inversion technique as in [15] and [16] in which we will adjust the prior CH_4 emission rate, derived from UBEI2017, in the process of matching the estimated CH_4 concentration to observed value to derive a posterior CH_4 emission rate. After that, we will determine the VOC emissions of the footprint using CH_4/VOC factors developed for each receptor as described above. CH_4 and VOC emissions from all footprints area will be averaged and normalized by number of oil and gas wells in the footprints, and then scaled up for the entire UB by using number of wells.

The above method for developing top-down VOC emission inventory differs from the method applied in VOCUB study which requires input from a gridded CH_4 emission data and contain certain uncertainty as discussed in [13]. Another difference from the VOCUB is that this project provides a multiyear estimation of top-down VOC emission inventory (2020 through 2022) that can be compared against O&G production rates in the same years to evaluate their correlations and to reveal trends in VOC emissions in the past years. Possible outcome of this analysis is set of scale factors to project top-down emissions from a base year to a target year using O&G production rates.

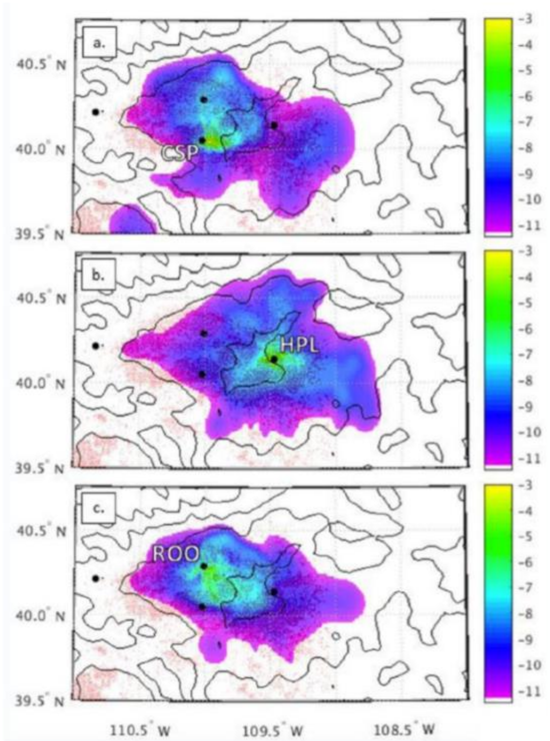

Figure 5. Map of the Uintah Basin showing the source region (aka "footprint") during the daytime over the duration of a cold-pool event (28 November 2015 to 6 December 2015) for the three key measurement sites: (a) Castle Peak, (b) Horsepool, and (c) Roosevelt. The units are in log(ppb(nanomoles m^{-2} s^{-1})$^{-1}$), representing the change in concentration (in ppb) at the receptor per unit emission ((nanomoles m^{-2} s^{-1})) at a particular portion of the source region. Underlying each map in dots are the locations of oil and gas wells. From [14].

Task 2. Improvement of VOC composition of selected source regions

Oil and gas field the UB are well separated with gas wells dominate over eastern region and oil wells dominate over western region (Fig. 1). Furthermore, according to the UBEI, there are quite clear distinction in emissions of different source categories. As shown in Figure 6 as example, emission of aromatics are highest over gas well with dehydrators (within vicinity of Horsepool); emissions of aldehydes are highest over oil wells with natural gas-fired engines (within vicinity of Castle Peak); and VOC emissions are lower over oil wells located north of Highway 40 (Roosevelt's vicinity).

We will perform VOC composition analyses on each footprints of Horsepool, Castle Peak and Roosevelt that well represent for the separated source regions as discussed above. A composite VOC composition profiles will be developed for each source regions based on CH_4 and VOC data at receptors when their footprints match the selected source regions. Specifically, CH_4 and VOC data at Castle Peak, Horsepool, and Roosevelt will be used for developing composition profiles for source regions within their immediate vicinity as discussed above.

We will perform statistical analyses to identify adjustments need to be made to the VOC composition profiles of each source categories (e.g., tanks, dehydrator, engines, etc.) located in a same source region so that their combined emissions would match the signature of the composite VOC composition of such source region. VOC composition profile of source categories that have been studied, such as in the Uintah Basin Composition Study [11], or well documented will be kept unchanged. VOC composition profiles that are not specific for UB are targeted for adjustment analyses.

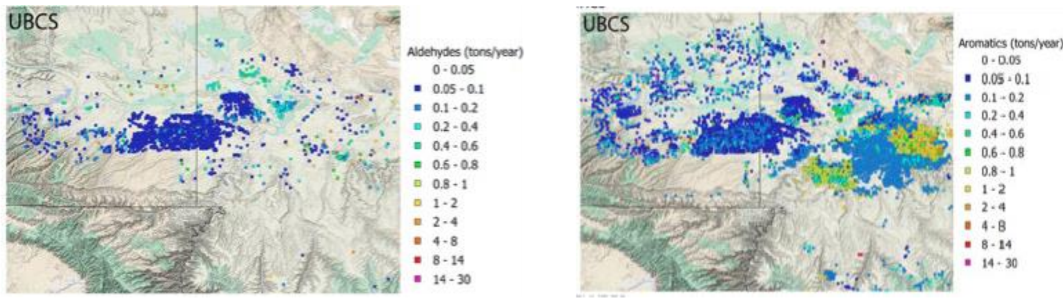

Figure 6. Emissions of aldehydes and aromatics (tons/year), allocated by well location, as derived from UBEI2014.

Task 3. Perform WRF/CAMx simulation for high ozone winter episode with using bottom-up and top-down EI

We will perform WRF/CAMx model simulations for a 10-day episode in winter 2020-2021 or winter 2021-2022, whichever has higher number of ozone exceedances, with using the 2021 top-down VOC emission inventory (TD) and with using the bottom-up (BU) UBEI2017 (or UBEI2020 when it becomes available). Emission of NO_X and other pollutants other than CH_4 and VOC in TD scenario will be kept at same value in BU. We evaluate CAMx performance in TD and BU with measured ozone, CH_4 and VOC at Horsepool, Roosevelt and Castle Peak and with VOC data collected from distributed canisters in the VOCUB study.

Task 4. Measurements of CH_4 and VOC in the Uinta Basin

We will continue the long-term CH_4 measurements at the same sites of Fruitland, Castlepeak, and Horsepool (Fig. 1) into 2022, observing through the winter of 2021-2022, and beyond. This will enable us to monitor the long-term trends in CH_4, to see whether the decreasing trend shown in Fig. 2 reverses due to economic or social factors, such as recovery from COVID-19-induced shutdowns.

We will leverage VOC measurements data Horsepool, Castle Peak and Roosevelt that USU has performed in the past winter season and will continue doing so in the future. The measurements are supported by USU's other funding sources and therefore cost for VOC measurement is not accounted in this project's budget.

The continuing of long-term measurement of CH_4 and VOC will lay the foundation for future studies to leverage CH_4 to inform VOC emissions in the Uintah Basin.

Task 5. Project Management and Reporting

The PI and co-PI will hold monthly meeting to discuss project progress, outcomes and obstacles, and strategies to overcome obstacle. The PI and co-PI will coordinate to prepare project's deliverables, as specified in section 5, and following the project timeline as specified in Table 3. The PI of the project will report to UDAQ and seek UDAQ's approval for any deviation of the project objectives and scopes of work throughout the course of the project.

Model configurations

Weather Research and Forecast (WRF) meteorological model configuration

We will use a WRF model configuration similar to the configuration that we performed for the UDAQ ozone SIP model [17]. Table 1 summarizes physical options used in the WRF model and Figure 7 depicts model domains.

Table 1. Physics options used in the WRF

WRF Treatment	Option Selected
Microphysics	Thompson
Longwave Radiation	RRTMG
Shortwave Radiation	RRTMG
Land Surface Model (LSM)	NOAH
Planetary Boundary Layer (PBL) scheme	MYJ
Cumulus parameterization	Kain-Fritsch in the 12 km domains. None in the 4 and 1.3 km domain.

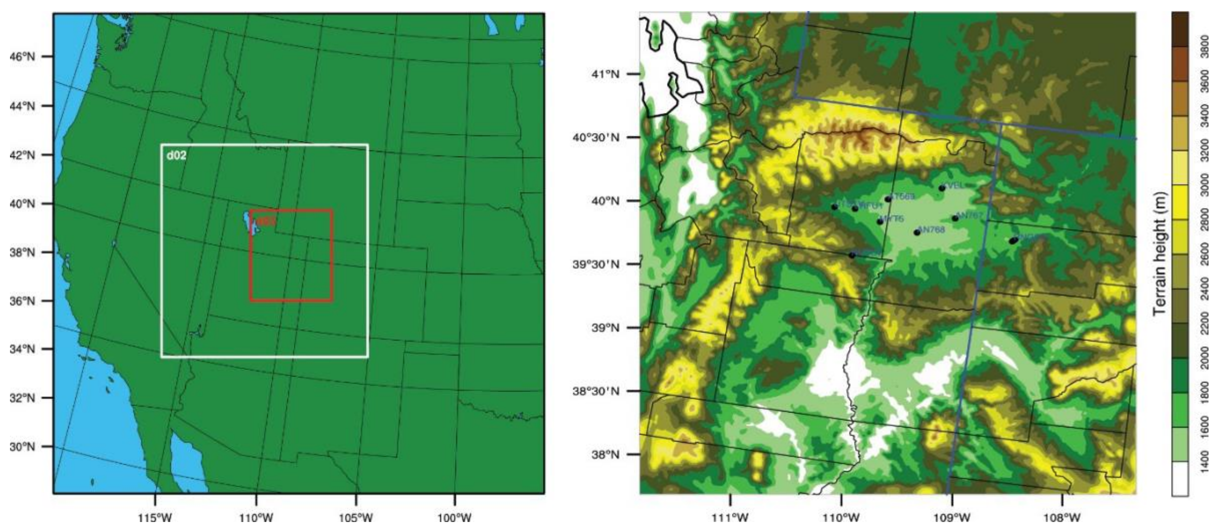

Figure 7. WRF one-way nested 12-4-1.33km domains (left) and zoom-in of 1.33km-domain with black circles indicating monitoring stations used for model performance evaluation (right).

Stochastic Time-Inverted Lagrangian Transport (STILT) model

The STILT model is a Lagrangian particle dispersion model originally developed by Co-PI John Lin [18] that has been widely applied to estimate greenhouse gas emissions and understand air quality issues [19, 20]. Most relevant for the proposed project is the successful application of STILT to estimate CH_4 emissions in the UB [2, 21] that has confirmed the high emissions derived from limited aircraft observations [1]. STILT simulates an ensemble of air parcels that are transported backward in time from selected receptors to determine the upwind source region (Fig. 5) affecting the receptors [18, 22]. In our proposal, STILT will be used to relate the measured values of CH_4 and VOC with upwind sources and thus in combination with an emission inventory, produce simulated values that can be compared against the observations. Discrepancies between STILT-simulated values against observations would then reveal deficiencies in the emission inventory that can be addressed. Meteorological inputs for STILT are taken from the High Resolution Rapid-Refresh model[2].

CAMx photochemical model

We will use the Comprehensive Air Quality Model (CAMx) version 6.5[3] in the same configuration of the 2017 Air Resource Management Strategy (ARMS) modeling study (Mansfield et al., 2020) in its finest domain (1.3 km), which is presented as ***d03*** in Figure 7. Table 2 provides details on the CAMx domain configurations.

Table 2. Summary of CAMx Model Configurations

Science Options	Configuration
Model Code Version	CAMx V6.5
Horizontal Grid	1.33 km (298x322)
Vertical Grid	25 vertical layers
Initial and Boundary conditions	Processed from ARMS2017
Boundary Conditions	12 km BCs from WAQS 2011b
Land-use Data	Land-use fields from meteorological model
Photolysis Rate Preprocessor	TUV V4.8 (Clear-sky photolysis rates from TOMS data)
Gas-phase chemistry	CB6r4
Aerosol-phase	CF (coarse and fine mode aerosols)
Diffusion Scheme	
Horizontal-grid	Explicit horizontal diffusion
Vertical-grid	K-theory 1st-order closure
Deposition Scheme	
Dry deposition	ZHANG03
Wet deposition	CAMx specific formulation
Numerical Solvers	
Gas-phase chemistry	Euler Backward Iterative (EBI) solver
Horizontal advection	Piecewise Parabolic Method (PPM)
Vertical advection	Implicit scheme with vertical velocity update

4. Expected Outputs and Outcomes

Expected output from this project is a multiyear estimation on top-down CH_4 and VOC emission inventory that could be used to ground-truth UDAQ's bottom-up UBEI. This project also develop a framework based on with future top-down EI could be developed with using ongoing CH_4 and VOC measurements in the UB. Additional output of this project is a set of refined VOC composition profiles for various O&G source categories based on ambient measurement. We also provide Outcome of this project is an increase confident in choice of emission inventory that is most suitable for conducting ozone SIP model and developing emission control strategies.

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[2] https://rapidrefresh.noaa.gov/hrrr/

[3] http://www.camx.com/files/camxusersguide_v6-50.pdf

5. Deliverables

Quarterly Progress Reports: As required by the RFP, USU and UoU will collaborate in preparing quarterly progress reports over the project performance period. The first quarterly reports would be submitted in October of 2021 and the last report would be submitted in December 2022.

Final Report: A draft final project report will be submitted to UDAQ within 90 days of project completion for reviews. We will compile the final report with addressing of comments and suggestions received on the draft report within the deadline then specified by UDAQ.

Conference Presentation: We will provide an oral or poster presentation at a Science for Solutions conference expectedly in 2023. The presentation would include study objectives, approach, results, and recommendations for future study. Feedbacks that we receive from the conference, if any, will be addressed in the Final report if the deadline has not been met.

Data Sharing: We will compile all measurement data, model inputs and outputs, data of estimated emission inventory and store on our data server for at least 1 year after the project completion date. All data will be delivered to UDAQ upon request, and/or delivered to 3rd party as specified by UDAQ.

The team would share with UDAQ all datasets and models developed during the course of the proposed project. We would arrange with UDAQ the most appropriate way to provide the data. Following the specifications of the RFP, all data to be shared would be made available within 8 months of project completion. We anticipate the following data would be generated and shared from this project:

6. Schedule

This project will begin in July 2021 and end in December 2022 (18 months). We will carry out this project according to the schedule shown in Table 3.

Table 3. Gantt chart showing project schedule.

	Jul-Sep 2021	Oct-Dec 2021	Jan-Mar 2022	Apr-Jun 2022	Jul-Sep 2022	Oct-Dec 2022	Jan-Mar 2023	Apr-Jun 2023
Task 1. Top-down EI development								
Task 2. Improving VOC composition profile								
Task 3. WRF-CAMx simulation for winter 2021 (or 2022)								
Task 4. CH_4 and VOC measurements								
Analysis and final report preparation								
Quarterly reports								
Final Report and Final Datasets								

Attendance at conferences								
Peer-reviewed publication								

7. Budget

Table 4 ad 5 presents the project budget for activities to be carried out by USU and UoU, respectively.

Table 4. Budget Summary for USU

		Task1	Task2	Task 3	Task 5	Matching Fund	Total Funded by UDAQ	Grand Total
PERSONNEL								
Huy Tran	Hours	120	120	200	138		578	578
	Dollar $41/hr	**4,920**	**4,920**	**8,200**	**5,658**		**23,698**	**23,698**
Seth Lyman	Hours	80			32	112	0	112
	Dollar $62/hr	**4,960**	**0**	**0**	**1,984**	**6,944**	**0**	**6,944**
BENEFITS	**@46.5%**	**4,594**	**2,288**	**3,813**	**3,554**	**3,229**	**11,020**	**14,249**
SUPPLIES							0	0
Computer Storage	**6 TB**					900	0	900
TRAVEL							0	0
Travel for 1, Sci. for Solns.						500	0	500
TOTAL DIRECT COSTS						**11,573**	**34,718**	**46,291**
TOTAL INDIRECT @10%						**1,157**	**3,472**	**4,629**
TOTAL PROJECT COST						**12,730**	**38,189**	**50,920**

Total budget estimated for USU is $50,920 which includes:

- Personnel costs ($44,891): 578 person-hours for Huy Tran at $41/hour and 112 person-hours for Seth Lyman at $62/hour, fringe benefits calculated as 46.5% of salaries.
- Supplies ($900): Data storage for model inputs and outputs on Utah CHPC system, estimated for 6 TB at $150/TB.
- Travel costs ($500): Travel costs for 1 person to the Utah Science for Solution conference during Spring 2023; costs assume one automobile round-trip from Vernal to Salt Lake City, with per-diem but without lodging.
- Indirect costs ($4,869): Facilities and administration costs are calculated as 10% of direct costs as allowed by the RFP.

USU will provide matching fund of $12,730 of the total budget. The requested fund from UDAQ for USU activities is $38,189.

Table 5. Budget Summary for UoU

	Description	Year 1	Year 2	Total
Start Date:	7/1/2021			
End Date:	12/31/2022	12 months	6 months	
Faculty Salaries	Faculty months per year	1.000	0.500	
	Faculty Salaries	**12,920**	**6,654**	**19,574**
Technician Salaries				
	Technician months per year	2	1.0	
	Technician Salary	**10,002**	**5,151**	**15,153**
	Total Personnel	**$22,922**	**$11,805**	**$34,727**
Benefits				
Faculty	Faculty benefits (34%)	4,393	2,262	6,655
Technician	Technician benefits (62%)	6,201	3,194	9,395
	Total Benefits	**10,594**	**5,456**	**16,050**
Travel				
	Travel to service sites	1,952	972	2,924
	Total Travel	**1,952**	**972**	**2,924**
Other Direct Costs				
	Expendables	350	0	350
	Pump rebuild kits	315	0	315
	Cellular data	1,080	540	1,620
	Los Gatos factory maintenance & calibration	3,500	0	3,500
	Filters	420	210	630
	Publication costs	0	1,000	1,000
	Total Other Direct Costs	**5,665**	**1,750**	**7,415**
	TOTAL Direct	**$41,133**	**$19,983**	**$61,116**
	Salaries + Fringe (Base)	33,516	17,261	50,777
	indirect	3,724	1,918	5,642
	Travel & Workshop (Base)	1,952	972	2,924
	indirect	217	108	325
	Other Direct (Base)	5,665	1,750	7,415
	indirect	629	194	824
	Modified Total Direct Costs (MTDC)	**41,133**	**19,983**	**61,116**
	TOTAL Indirect	**4,570**	**2,220**	**6,791**
	GRAND TOTAL	**$45,703**	**$22,203**	**$67,906**

Budget Narrative for UoU

The University of Utah (UoU) subaward includes salary for Co-I J. Lin and a research associate (Dr. Maria Garcia) at 1.5-month and 3 months per year (over 1.5 years) to help with both the STILT modeling, analyses, and the methane measurements. The budget also includes supplies for the methane observations and travel to the sites, to support these measurements for the duration of the project. Budget to defray publication cost for a peer-reviewed paper ($1000) is also included.

8. Personnel Roles and Responsibilities

Dr. Huy Tran (USU) will serve as the project principal investigator. Dr. Tran will lead the improving VOC composition (Task 2), performing and evaluation of WRF/CAMx model (Task3), and preparing reports (Task 5). He will assist the co-PI (Dr. John Lin) the development of top-down emission inventories (Task 1).

Dr. Tran has more than 10 years performing research as an air quality modeler and has experience with various modeling system including meteorology models (WRF, MM5), dispersion models (AERMOD, CALPUFF), receptor models (CMB, PMF) and photochemical models (CAMx, CMAQ). He carried out researches involving modifying source codes of WRF and CAMx model and so gained extensive understanding on the models' structure. He is also the PI of the VOCUB project on which is this project is elevated.

Dr. Seth Lyman (USU) will serve as a technical advisor on the project, prepare VOC measurement data for developing of the top-down emission inventory and for model performance evaluation. He will aid the PI and co-PI in overall study execution, analysis, and report writing.

Dr. Lyman has successfully completed a wide array of air quality research projects during his career, including emissions measurements from oil and gas sources and ambient air quality measurement campaigns. He has more than nine years of experience researching the wintertime ozone issue in the Uinta Basin.

Dr. John Lin (UoU) will serve as the co-PI of the project. He'll take lead in the development of top-down emission inventories (Task 1) and work with other modelers in the team on how to carry out analyses using output from the STILT model. Dr. Lin will also take lead in carrying out long-term measurement of CH_4 in the UB. He will assist the project PI in preparing project deliverables (Task 5).

John C. Lin is currently a Professor in the Dept. of Atmospheric Sciences at the University of Utah. Lin's research is focused on air quality and greenhouse gases and has expertise in modeling of greenhouse gases, pollutants, and inverse analyses for ~20 years. Since 2018 he has also been a Science Team member of the World Meteorological Organization's Integrated Global Greenhouse Gas Information System (IG3IS). Lin has extensive experience in Lagrangian modeling of the atmosphere and is the original author of the STILT atmospheric model. He served as the Convener for AGU's prestigious Chapman Conference on "Advances in Lagrangian Modeling of the Atmosphere" and was the Chief Editor of an AGU Geophysical Monograph on Lagrangian Modeling.

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APPENDIX A

Resumes of Key Personnel

APPENDIX B

Letter of commitment to proposed project to the Utah Division of Air Quality